

CLAIMS

What is claimed is:

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1. An apparatus for treating a wastewater comprising:
- a gas-enrichment assembly adapted to receive the wastewater and a treatment gas,
- wherein the gas-enrichment assembly is configured to generate a gas-enriched fluid; and
- a delivery assembly coupled to the gas-enrichment assembly for receiving the gas-enriched fluid from the gas-enrichment assembly, the delivery assembly expelling the gas-enriched fluid in a substantially bubble-free manner.
2. The apparatus of claim 1, wherein the wastewater comprises municipal reservoir water.
3. The apparatus of claim 1, wherein the wastewater comprises industrial waste.
4. The apparatus of claim 1, wherein the wastewater comprises lake/pond water.
5. The apparatus of claim 1, wherein the wastewater comprises river/stream water.
6. The apparatus of claim 1, wherein the wastewater comprises sewage.

7. The apparatus of claim 1, wherein the wastewater comprises stormwater runoff.
8. The apparatus of claim 1, wherein the wastewater comprises ground water.
9. The apparatus of claim 1, wherein the wastewater comprises aquacultural waters.
10. The apparatus of claim 1, wherein the wastewater comprises marine hatchery waters.
11. The apparatus of claim 1, wherein the wastewater comprises agricultural waste.
12. The apparatus of claim 1, wherein the wastewater comprises pesticides.
13. The apparatus of claim 1, wherein the wastewater comprises fertilizers.
14. The apparatus of claim 1, wherein the wastewater comprises heavy metals.
15. The apparatus of claim 1, wherein the wastewater comprises microorganisms.
16. The apparatus of claim 1, wherein the treatment gas comprises air.
17. The apparatus of claim 1, wherein the treatment gas comprises oxygen.

18. The apparatus of claim 1, wherein the treatment gas comprises ozone.
19. The apparatus of claim 1, wherein the treatment gas comprises hydrogen.
20. The apparatus of claim 1, wherein the treatment gas comprises chlorine.
21. The apparatus of claim 1, wherein the treatment gas comprises carbon monoxide.
22. The apparatus of claim 1, wherein the gas-enriched fluid is approximately gas-saturated by the treatment gas.
23. The apparatus of claim 1, wherein the gas-enriched fluid is gas-supersaturated by the treatment gas.
24. The apparatus of claim 1, wherein the gas-enrichment assembly is configured for substantially dissolving the treatment gas into the wastewater to a desired gas content, the desired gas content generally increasing with an operating pressure of the gas-enrichment assembly.
25. The apparatus of claim 24, wherein the desired gas content ranges from approximately 275 to 880 ppm for operating pressures of approximately 100 to 300 psi.
26. The apparatus of claim 25, wherein the treatment gas comprises oxygen.

27. The apparatus of claim 1, wherein the gas-enrichment assembly comprises:
 a pressurizable chamber having a gas inlet and a gas-enriched fluid outlet; and
 an atomizer assembly disposed within the pressurizable chamber, the atomizer assembly
 configured for receiving the wastewater and for atomizing the wastewater into the
 pressurizable chamber.

28. The apparatus of claim 27, wherein the atomizer assembly comprises:
 a stinger assembly having a conduit adapted to carry the wastewater, and at least one
 nozzle operatively coupled to the conduit to atomize the wastewater into the
 pressurizable chamber.

29. The apparatus of claim 27, wherein the atomizer assembly comprises:
 at least one nozzle disposed adjacent an inner wall of the pressurizable chamber, the
 nozzle configured for atomizing the wastewater into the pressurizable chamber.

30. The apparatus of claim 1, wherein the delivery assembly comprises:
 a fluid conduit; and
 a nozzle coupled to the fluid conduit.

31. The apparatus of claim 30, wherein the fluid conduit comprises a hose.

32. The apparatus of claim 30, wherein the nozzle comprises a plurality of fluid
 passageways configured to expel the gas-enriched fluid in a substantially bubble-free manner.

33. The apparatus of claim 32, wherein the fluid passageways have cross-sectional areas and lengths that are adapted to provide a laminar flow and to substantially preserve a dissolved gas content of the treatment gas in the gas-enriched fluid, while preventing excess clogging of the fluid passageways.

34. The apparatus of claim 32, wherein the fluid passageways comprise cylindrical conduits having a length of approximately 1.5 inches and a diameter of approximately 0.005 inches.

35. The apparatus of claim 30, wherein the nozzle comprises:
a plurality of stacked plates defining a plurality of fluid channels therebetween, the fluid channels having an inlet fluidically coupled to the fluid conduit and having an outlet for expelling the gas-enriched fluid.

36. The apparatus of claim 35, wherein the stacked plates comprise a substantially flat section.

37. The apparatus of claim 35, wherein the stacked plates comprise a substantially conical section.

38. The apparatus of claim 30, wherein the nozzle comprises:
a plurality of capillaries, each of the capillaries having an inlet fluidically coupled to the fluid conduit and having an outlet for expelling the gas-enriched fluid.

39. The apparatus of claim 38, wherein the capillaries have an inner diameter of approximately 150 to 450 microns.

40. The apparatus of claim 38, wherein the capillaries are grouped into a plurality of capillary bundles.

41. The apparatus of claim 40, wherein the capillary bundles comprise a bonding material disposed about the capillary bundles.

42. The apparatus of claim 1, comprising at least one filter assembly coupled to the gas-enrichment assembly.

43. The apparatus of claim 42, wherein the filter assembly comprises a series of increasingly fine filters.

44. The apparatus of claim 42, wherein the filter assembly comprises a 150 micron filter.

45. The apparatus of claim 42, wherein the filter assembly comprises a self-cleaning filter.

46. The apparatus of claim 42, wherein the filter assembly is disposed between the gas-enrichment assembly and a wastewater inlet.

47. The apparatus of claim 42, wherein the filter assembly is fluidically coupled to the delivery assembly for filtering the gas-enriched fluid.

48. The apparatus of claim 1, comprising a control system coupled to the gas-enrichment assembly and coupled to the delivery assembly, the control system at least providing control of a wastewater flowrate and a treatment gas flowrate entering the gas-enrichment assembly, and control of a gas-enriched wastewater flowrate exiting the gas-enrichment assembly through the delivery assembly.

49. A method of treating a wastewater comprising the acts of:
pressurizing a vessel with a treatment gas; and
delivering the wastewater, in an atomized state, into the vessel to gas-enrich the wastewater to a desired gas content.

50. The method of claim 49, comprising the acts of:
withdrawing the wastewater from a supply of wastewater to be treated; and
expelling the wastewater, at about the desired gas content, back into the supply of wastewater.

51. The method of claim 49, comprising the act of atomizing the wastewater.

52. The method of claim 49, comprising the act of filtering the wastewater.

53. The method of claim 52, wherein the act of filtering comprises passing the wastewater through a series of increasingly fine filters.

54. The method of claim 52, wherein the act of filtering comprises passing the wastewater through a 150 to 450 micron filter.

55. The method of claim 52, wherein the act of filtering the wastewater comprises passing the wastewater through a self-cleaning filter.

56. The method of claim 49, comprising the act of:
delivering the wastewater to the vessel through a stinger disposed within the vessel, the stinger having a pipe adapted to carry the wastewater and at least one nozzle, operatively coupled to the pipe, to atomize the wastewater into the vessel.

57. The method of claim 49, comprising the act of:
delivering the wastewater to the vessel through at least one nozzle disposed adjacent to an inner wall of the vessel, the nozzle atomizing the wastewater into the vessel.

58. The method of claim 49, comprising the acts of:
expelling the wastewater from the vessel through a fluid conduit; and
passing the wastewater through a nozzle coupled to the fluid conduit.

59. The method of claim 58, wherein the act of expelling the wastewater comprises the act of passing the wastewater through a hose.

60. The method of claim 58, wherein the act of passing the wastewater through the nozzle comprises the act of:

passing the wastewater through a plurality of fluid passageways dimensioned to provide a substantially laminar and bubble-free flow.

61. The method of claim 58, wherein the act of passing the wastewater through the nozzle comprises the act of:

passing the wastewater through a plurality of stacked plates defining a plurality of fluid channels therebetween, the fluid channels having an inlet fluidically coupled to the fluid conduit and having an outlet.

62. The apparatus of claim 58, wherein the act of passing the wastewater through the nozzle comprises the act of:

passing the wastewater through a plurality of capillaries, each of the capillaries having an inlet fluidically coupled to the fluid conduit and having an outlet.

63. A wastewater treatment facility comprising:

a gas-enrichment assembly adapted to receive a supply of wastewater and a supply of treatment gas, wherein the gas-enrichment assembly is configured to gas-enrich the wastewater to a desired gas content of the treatment gas in a substantially bubble free manner; and

a delivery assembly coupled to the gas-enrichment assembly to receive and expel the wastewater from the gas-enrichment assembly, wherein the delivery assembly is configured to substantially preserve the desired gas content and to substantially eliminate bubble formation.

64. The facility of claim 63, comprising a mounting assembly configured to support the gas-enrichment assembly and the delivery assembly.

65. The facility of claim 64, wherein the mounting assembly is configured for fixed mounting at a stationary wastewater treatment site.

66. The facility of claim 64, wherein the mounting assembly is configured to be coupled to a mobile deployment system.

67. The facility of claim 66, wherein the mobile deployment system comprises a motor driven vehicle.

68. The facility of claim 66, wherein the mobile deployment system comprises a trailer configured for towing behind a motor driven vehicle.

69. The facility of claim 66, wherein the mobile deployment system comprises a at least one cart.

70. The facility of claim 63, comprising a treatment gas supply configured to provide treatment gas for the gas-enrichment assembly.

71. The facility of claim 63, wherein the gas-enrichment assembly comprises: a pressurizable chamber having a gas inlet and a gas-enriched fluid outlet; and an atomizer assembly disposed within the pressurizable chamber, the atomizer assembly configured for receiving the wastewater and for atomizing the wastewater into the pressurizable chamber.

72. The facility of claim 63, wherein the delivery assembly comprises: a fluid conduit; and a nozzle coupled to the fluid conduit.

73. The facility of claim 66, wherein the nozzle comprises a plurality of fluid passageways configured to expel the wastewater, at the desired gas content, in a substantially bubble-free manner.

74. The facility of claim 63, comprising at least one filter assembly for filtering the wastewater.

75. The facility of claim 63, comprising a control system coupled to the gas-enrichment assembly and coupled to the delivery assembly, the control system at least providing control of the desired gas content and control of an exit flowrate of wastewater expelled through the delivery assembly.